| GLAST LAT SYSTEM SPECIFICATION | Document # LAT-SS-00018-D7 | Date Effective 19 July 2001 |
|---|---|---|
| | Prepared by(s) W. Neil Johnson | Supersedes None |
| | Subsystem/Office Calorimeter Subsystem | |
| Document Title LAT CAL Subsystem Specification - Level III Specification | | |

# DRAFT D7

Post Requirements Review

## Gamma-ray Large Area Space Telescope (GLAST)

## Large Area Telescope (LAT)

## Calorimeter (CAL) Subsystem Specification

# CHANGE HISTORY LOG

| Revision | Effective Date | Description of Changes | DCN # |
|---|---|---|---|
| 1 | | Initial Release | |
| | | | |
| | | | |
| | | | |
| | | | |

# 1 PURPOSE

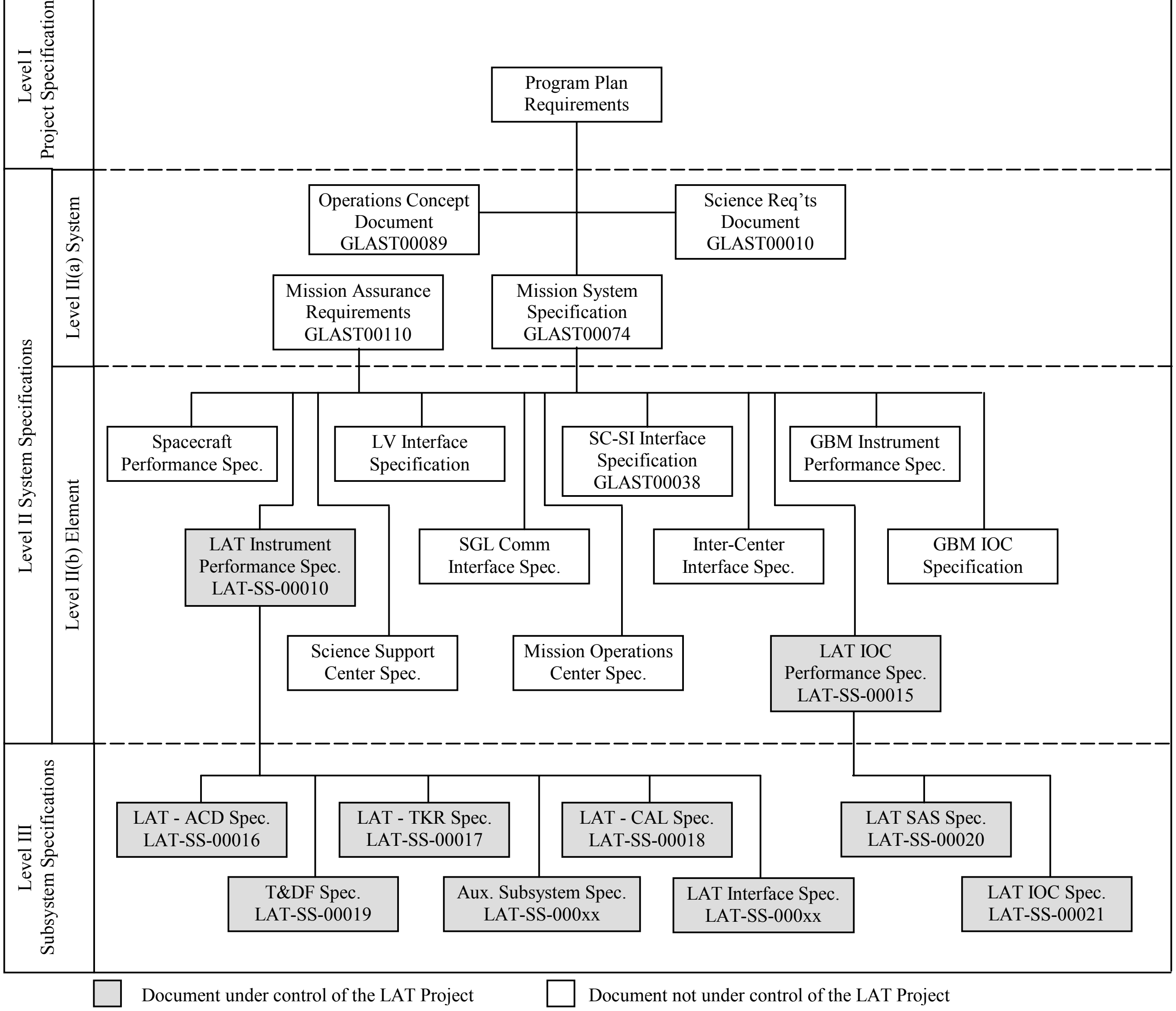
This document defines level III subsystem requirements for the GLAST Large Area Telescope (LAT) Calorimeter (CAL).

# 2 SCOPE

This specification captures the GLAST LAT requirements for the CAL. This encompasses the subsystem level requirements and the design requirements for the CAL. The verification methods of each requirement are identified.

This specification is identified in the specification tree of Figure 2-1.

FIGURE 2-1 SPECIFICATION TREE



# 3 DEFINITIONS

## 3.1 Acronyms

| | |
|---|---|
| AGN | Active Galactic Nuclei |
| CAL | LAT calorimeter subsystem |
| FOV | Field of View |
| FWHM | Full Width Half Maximum |
| GLAST | Gamma-ray Large Area Space Telescope |
| IRD | Interface Requirements Document |
| LAT | Large Area Telescope |
| SRD | Science Requirements Document |
| TBR | To Be Resolved |

## 3.2 Definitions

| | |
|---|---|
| $\gamma$ | Gamma Ray |
| μsec, μs | Microsecond, $10^{-6}$ second |
| $A_{eff}$ | Effective Area |
| Analysis | A quantitative evaluation of a complete system and /or subsystems by review/analysis of collected data. |
| Arcmin | An arcmin is a measure of arc length. One arcmin is 1/60 degree. |
| Background Rejection | The ability of the instrument to distinguish gamma rays from charged particles. |
| Backsplash | Secondary particles and photons originating from very high-energy gamma-ray showers in the calorimeter giving unwanted ACD signals. |
| Beam Test | Test conducted with high energy particle beams |
| cm | centimeter |
| Cosmic Ray | Ionized atomic particles originating from space and ranging from a single proton up to an iron nucleus and beyond. |
| Dead Time | Time during which the instrument does not sense or record gamma ray |

| | |
|---|---|
| | events during normal operations. |
| Demonstration | To prove or show, usually without measurement of instrumentation, that the project/product complies with requirements by observation of results. |
| eV | Electron Volt |
| Field of View | Integral of effective area over solid angle divided by peak effective area. |
| GeV | Giga Electron Volts. $10^9$ eV |
| Inspection | To examine visually or use simple physical measurement techniques to verify conformance to specified requirements. |
| MeV | Million Electron Volts, $10^6$ eV |
| ph | photons |
| s, sec | seconds |
| Simulation | To examine through model analysis or modeling techniques to verify conformance to specified requirements |
| sr | steradian, A steradian is the solid (3D) angle formed when an area on the surface of a sphere is equal to the square of the radius of the sphere. There are 4 Pi steradians in a sphere. |
| Testing | A measurement to prove or show, usually with precision measurements or instrumentation, that the project/product complies with requirements. |
| Validation | Process used to assure the requirement set is complete and consistent, and that each requirement is achievable. |
| Verification | Process used to ensure that the selected solutions meet specified requirements and properly integrate with interfacing products. |

# 4 APPLICABLE DOCUMENTS

Documents that are relevant to the development of the GLAST mission concept and its requirements include the following:

LAT-SS-00010, “GLAST LAT Performance Specification”, August 2000

GSFC 433-SRD-0001, “GLAST Science Requirements Document”

GSFC 433-IRD-0001, “GLAST Science Instrument – Spacecraft Interface Requirements Document”, Draft July 14, 2000

GSFC 433-SPEC-0001, “GLAST Mission System Specification”, Draft, June 30, 2000

GSFC 433-OPS-0001, “GLAST Operations Concept”

GSFC 433-MAR-0001, "Mission Assurance Requirements (MAR) for Gamma-Ray Large Area Telescope (GLAST) Large Area Telescope (LAT)"

# 5 REQUIREMENTS

## 5.1 System Description

The LAT science instrument (SI) consists of an Anticoincidence Device (ACD), a silicon-strip detector tracker (TKR), a hodoscopic CsI calorimeter (CAL), and a Trigger and Dataflow system (T&DF). The principal purpose of the SI is to measure the incidence direction, energy and time of cosmic gamma rays. The measurements are streamed to the spacecraft for data storage and subsequent transmittal to ground-based analysis centers.

The CAL provides the energy measurement of incident photons and background particles. These measurements, along with the information in the TKR, are used to reconstruct the energy of the incident photons. These CAL measurements are also critical to the background particle identification and rejection. The CAL responds to T&DF requests by digitizing the energy loss in the CAL and outputs the data to the dataflow system. The CAL also provides fast signals to the T&DF system that report significant energy depositions in CAL. The T&DF system analyzes these fast signals to form requests for data readout of GLAST.

The CAL subsystem consists of a $4 \times 4$ array of identical modules. Each module is a hodoscopic array of CsI scintillation crystals and associated readout electronics.

## 5.2 Energy Measurement Range

### 5.2.1 Energy Range Low Limit

[Derived from LAT SS-00010 5.2.1]

The calorimeter measurement range shall have a low energy threshold of 5 MeV.

The goal is to achieve a low energy threshold of 1 MeV.

[COMMENT: This is a measurement threshold of a single crystal, not the ability to measure 5 MeV photons incident on the calorimeter.]

### 5.2.2 Energy Range High Limit

[Derived from LAT SS-00010 5.2.1]

The calorimeter measurement range shall have a high energy limit greater than 300 GeV.

The goal is to achieve a high energy measurement limit of 1 TeV.

[COMMENT: This measurement is from the sum of all calorimeter crystals.]

### 5.2.3 Single CsI Crystal Energy Measurement Range

[Derived from LAT SS-00010 5.2.1]

The energy measurement range for each of the CsI scintillation crystals shall include the range from 5 MeV to 100 GeV.

The goal is to achieve a low energy threshold of 1 MeV.

## 5.3 Energy Resolution

### 5.3.1 On-axis Energy Resolution – Low Energies

[Derived from LAT SS-00010 5.2.2]

The energy resolution (1σ) shall be better than 20% (TBR) for normal incidence photons for energies in the 20 – 100 MeV range that interact in the calorimeter only. The energy resolution (1σ) shall be less than 10% for photons for energies in the 100 MeV – 10 GeV range.

Note: Low energy measurements require contributing TKR energy loss measurement to achieve specified resolution.

### 5.3.2 On-axis Energy Resolution – High Energies

[Derived from LAT SS-00010 5.2.2]

The energy resolution (1σ) shall be better than 20% for photons, with on-axis incidence, for energies in the 10 – 300 GeV range.

### 5.3.3 Off-axis Energy Resolution – High Energies

[SRD Table 1, #7]

The energy resolution (1σ) shall be less than 6% for photons, with angles of incidence >60 degrees off axis, for energies greater than 10 GeV. The effective area for these off-axis measurements with this energy resolution is expected to be 10 – 20% of the on-axis effective area at energies greater than 10 GeV.

The goal is less than 3%.

### 5.3.4 Single Crystal Energy Resolution

[Derived from LAT SS-00010 5.2.2]

The energy resolution (1σ) shall be less than 1% for high energy (>100 MeV/nucleon) Carbon ions of normal incidence at a central point in the crystal with beam spot size less than 3 mm diameter.

## 5.4 On-Orbit Calibration

[Derived from LAT SS-00010 5.2.2]

The calorimeter shall be capable of energy calibration in orbit using energy depositions from the array of cosmic ray particles. Relative light yield in each crystal shall be determined to better than 3%. Absolute light yield shall be determined to better than 10%.

The goals for relative and absolute yield are < 1% and < 3%.

## 5.5 Hodoscopic Configuration

### 5.5.1 Depth

[Derived from LAT SS-00010 5.2.2]

The calorimeter shall have an active depth of greater than 8.4 (TBR) radiation lengths of CsI for normally incident particles.

### 5.5.2 Hodoscopic Layers

[Derived from LAT SS-00010 5.2.2]

The calorimeter module shall be hodoscopic.

### 5.5.3 Active Area

[Derived from LAT SS-00010 5.2.2]

Each calorimeter module shall provide a projected CsI area of greater than 1050 $cm^2$ (TBR). for normally incident particles.

### 5.5.4 Passive Material

[Derived from LAT SS-00010 5.2.2]

Passive material in a calorimeter module (everything not CsI) shall represent no more than 16% (TBR) of the total mass of the module.

### 5.5.5 Position Resolution

[Derived from LAT SS-00010 5.2.2, 5.2.12]

Each layer of the calorimeter shall position the centroid of a Minimum Ionizing charged particle energy deposition to less than 1.75 cm (1$\sigma$) in all three dimensions for particle incident angles of less than 45 degrees off axis.

### 5.5.6 Angular Resolution

[Derived from LAT SS-00010 5.2.2, 5.2.12]

The single particle angular resolution at 68% containment for the calorimeter shall be better than ~~$7.5 \times \cos^2(\theta)$~~$8.5 \times \cos^2(\theta)$ degrees (TBR) for cosmic muons traversing all eight layers. ($\theta$ is the off-axis angle.)

## 5.6 Command and Data Interface

The calorimeter electronics shall communicate with the Trigger and Data Flow (T&DF) subsystem using LAT standard communications protocols.

## 5.7 Measurement Dead Time

[LAT SS-00010 5.2.13]

The dead time associated with the capture and measurement of the energy depositions shall be less than 100 μsec. The goal is less than 20 μsec.

## 5.8 Overload Recovery

[Derived from LAT SS-00010 5.2.2, 5.2.13]

The calorimeter electronics shall be capable of recovery from a x1000 overload within ~~500~~100 μsec. Recovery is defined as below the measurement readout (zero suppression) threshold.

## 5.9 Low Energy Trigger Signal

[Derived from LAT SS-00010 5.2.1, 5.2.3]

The calorimeter shall provide a prompt (within 2 μs of an event) low-energy trigger signal to the LAT trigger system with a detection efficiency of greater than 90% (TBR) for 1 GeV gamma rays entering the calorimeter from the LAT field of view with a trajectory which traverses at least 6 RL of CsI.

## 5.10 High Energy Trigger Signal

[Derived from LAT SS-00010 5.2.1, 5.2.3]

The calorimeter shall provide a prompt (within 2 μs of an event) high-energy trigger signal with a detection efficiency of greater than 90% for 20 GeV gamma rays entering the calorimeter from the LAT field of view that deposit at least 10 GeV in the CsI of the calorimeter.

## 5.11 Operating Modes

[Derived from LAT SS-00010 5.3.5]

The calorimeter shall be capable of operating continuously throughout the orbit. Operating through traversals of the South Atlantic Anomaly shall not damage the calorimeter but, because of the excessive background rates, the acquired data shall not be required to meet performance specifications.

## 5.12 Calorimeter Mass

[Derived from LAT SS-00010 5.3.6]

Total mass of the calorimeter shall not exceed 1492 kg. (**TBR**)

[COMMENT: SRR mass estimate plus 10% of ANSI/AIAA estimated reserves]

## 5.13 Calorimeter Power

[Derived from LAT SS-00010 5.3.10]

The power consumption of the calorimeter system, excluding conditioning, shall not exceed 91 W **(TBR)**

[COMMENT: Lehman review power adjusted for 80% efficiency of converters]

## 5.14 Environmental

The CAL shall be capable of normal operation after being subjected to the environmental conditions given in LAT-SS-00010, Section 5.3.12, Environmental.

## 5.15 Performance Life

NOTE: Performance Life specifications need updating. Thurston has action item from 3/28/01 review to provide specifications and rationale for CAL reliability and operability.

### 5.15.1 Reliability

[Derived from LAT SS-00010 5.3.2]

The probability that the calorimeter will experience a complete loss of operation due to the failure of any of its components shall be less than 0.8% (**TBR**) in 5 years.

### 5.15.2 Operability

[Derived from LAT SS-00010 5.3.2]

The calorimeter shall be designed such that the failure or degradation of components at the predicted rate shall not result in a loss of more than 10% (TBR) of the effective area in 5 years.

# 6 VERIFICATION STRATEGY

The verification strategy will test, analyze (may include modeling/simulation), inspect, or demonstrate all requirements of section 5 to ensure that the instrument meets its specified requirement. The matrix below indicates the methods of verification employed to verify the science performance.

**Table 6-1. Requirements Verification Matrix**

Note: Verification methods are T = Test, A = Analysis, D = Demonstrate, I = Inspect

| Req't # | Title | Summary | Verif. Method |
|---|---|---|---|
| 5.2.1 | Energy Range Low Limit | 5 MeV | A |
| 5.2.2 | Energy Range High Limit | >300 GeV | A |
| 5.2.3 | Single CsI Crystal Energy Measurement Range | 5 MeV – 100 GeV | A |
| 5.3.1 | On-axis Energy Resolution – Low Energies | <50% (20 – 100 MeV)<br><10% (100 MeV – 10 GeV) | A |
| 5.3.2 | On-axis Energy Resolution – High Energies | <20% (10 – 300 GeV) | A |
| 5.3.3 | Off-axis Energy Resolution – High Energies | <6% (> 10 GeV) | A |
| 5.3.4 | Single Crystal Energy Resolution | < 1% for high energy carbon | T,A |
| 5.4 | On-Orbit Calibration | Relative: <3%; Absolute <10% | A |
| 5.5.1 | Depth | > 8.4 radiation lengths of CsI | I |
| 5.5.2 | Hodoscopic Layers | Hodoscopic design | I |
| 5.5.3 | Active Area | >1050 $cm^2$/module on axis | I |
| 5.5.4 | Passive Material | No more than 16% of total mass of CAL | I |
| 5.5.5 | Position Resolution | < 1.5 cm in all 3 dimensions/layer | T |
| 5.5.6 | Angular Resolution | $<7.5 \times \cos^2(\theta)$ degrees for cosmic muons | T |
| 5.6 | Command and Data Interface | LAT standard protocols | I |
| 5.7 | Measurement Dead Time | <100 μsec | T |
| 5.8 | Overload Recovery | <500 μsec | T |
| 5.9 | Low Energy Trigger Signal | CAL to provide low-energy trigger signal to the LAT trigger system | I |
| 5.10 | High Energy Trigger Signal | CAL to provide high-energy trigger signal to the LAT trigger system | I |
| 5.11 | Operating Modes | Continuous thru orbits | A |
| 5.12 | Calorimeter Mass | Not to exceed 1492 kg (TBR). | I |
| 5.13 | Calorimeter Power | Not to exceed 91 W (TBR). | T |
| 5.14 | Environmental | Must withstand environmental conditions in LAT Instrument Performance Spec. | T |
| 5.15.1 | Reliability | < 0.8% probability of total failure | A |
| 5.15.2 | Operability | < 10% loss in effective area | A |